# Accuracy of a new apex locator: an *in vitro* study

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## Abstract

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**Aim** The purpose of this study was to test in an *in vitro* model the accuracy of a Bingo 1020 electronic apex locator, to compare the results to those of a well known apex locator, Root ZX, as well as to those of the radiographic method of tooth length determination.

**Methodology** A total of 120 extracted teeth, preserved in Thymol solution and kept refrigerated, was used for the study. The experiment was performed on single-rooted teeth and on one-root canal, chosen randomly, in multirooted teeth. The teeth were randomly divided into 12 groups of 10 teeth each. After access preparation, the actual length (AL) was measured. The teeth were embedded in an alginate model specially developed for testing apex locators. Electronic tooth length measurements (EL) were carried out prior to root canal preparation using the two electronic apex locators (EAL) – Root ZX and Bingo 1020; three measurements were taken and an average computed. After the third measurement, the file was left in the root canal and a periapical radiograph was taken. The radiographic length (RL) was recorded by measuring the file length from the coronal reference point to the tip of the file. Each root canal was then prepared to a no. 40 K-file diameter using a standardized technique; saline was used for irrigation. Upon completion of the root canal preparation, EL measurements were taken by each EAL in dry conditions and with different irrigation solutions. Each measurement was repeated three times. The RL was recorded according to the last EL measurement. Results were subjected to statistical analysis.

**Results** In all parameters tested, a significant statistical difference was found between Bingo 1020 and the Root ZX. Measurements obtained using the Bingo 1020 were consistently closer to the AL (0.08 mm) than those obtained using the Root ZX. Both EALs measured the tooth length with great accuracy and a positive correlation of 0.76 ($P = 0.00$) existed between the two devices. No significant difference was found between the two apex locators when measurements were taken with the different irrigants ($P = 0.34$) and the content of the root canal did not affect the accuracy of the measurements. Lengths obtained by calculations from the radiographs were longer than the AL as well as the length obtained by both EALs ($P = 0.00$).

**Conclusions** The Bingo 1020 proved to be as reliable as Root ZX and was user friendly. Under the experimental conditions, electronic measurements were more reliable than radiographs in the process of root length determination.



**Keywords:** Bingo 1020, electronic apex locator, irrigation solutions, radiography, root length determination, Root ZX.

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## Introduction

Recently, electronic methods for tooth length determination have gained popularity. Many studies report on the accuracy achieved by the new generation of electronic apex locators (EALs) as well as their extended measurement capabilities, which include accurate measurements in the presence of electrolytes (Fouad *et al.* 1993, Frank & Torabinejad 1993, Mayeda *et al.* 1993, Kobayashi 1995). Moreover, it has been reported that radiographic methods for tooth length determination might be less accurate than the electronic method (Stein & Corcoran 1992).

Most studies on EALs using two frequencies (the third generation) report accuracy rates of 85–95% (Fouad

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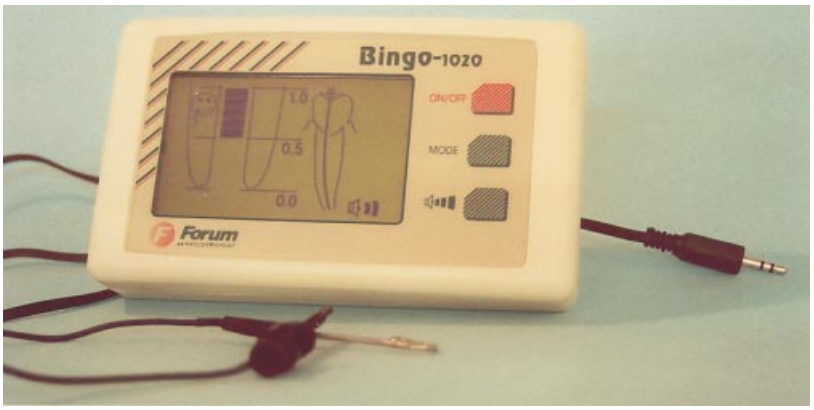


**Figure 1** The Bingo 1020 EAL.

*et al*. 1993, Frank & Torabinejad 1993, Mayeda *et al*. 1993, Weiger *et al*. 1999). Recently, a new apex locator, Bingo 1020 (Forum Engineering Technologies, Rishon Lezion, Israel) has been introduced (Fig. 1). The manufacturer claims that this apex locator may be regarded as the fourth generation of EALs. Similar to the third generation of EALs, the device uses two separate frequencies, 400 Hz and 8 KHz, produced by a variable frequency generator. Unlike the latter devices, the Bingo 1020 uses only one frequency at a time. The use of a single frequency signal eliminates the need for filters that separate the different frequencies of the complex signal. This prevents the noise inherent in such filters and increases measurement accuracy. In addition, the calculations of the position of the file tip in Bingo 1020 are based on measurements of root mean square (RMS) values of the signals. RMS expresses the energy of the measured signal and is more immune to various noises or signal distortions than other parameters of the signal, such as amplitude or phase, that are used in other devices. The manufacturers claim that the combination of these two techniques increases the measurement accuracy and the reliability of the device (Apex Locator Bingo-1020 1999). However, these claims have not been substantiated.

The objectives of the present study were to test the Bingo 1020 in an *in vitro* model and to compare its accuracy to the actual tooth length, to another apex locator (Root ZX, Morita, Tokyo, Japan), and to results obtained radiographically.

## Materials and methods

A total of 120 extracted multi- and single-rooted teeth, preserved in Thymol solution and kept refrigerated, was used for the study. Access cavities were prepared (Tungsten carbide 1157, SS White Burs, NJ, USA) and in each multirooted tooth, one canal was randomly chosen for study. The actual length (AL) was measured with the aid of a binocular microscope (×5) (Wild M-8, Leitz LTD, Heerbrugg, Switzerland) by introducing a no. 10 or no. 15 K-file until it emerged in the apical foramen. Each measurement was repeated three times and the mean value computed.

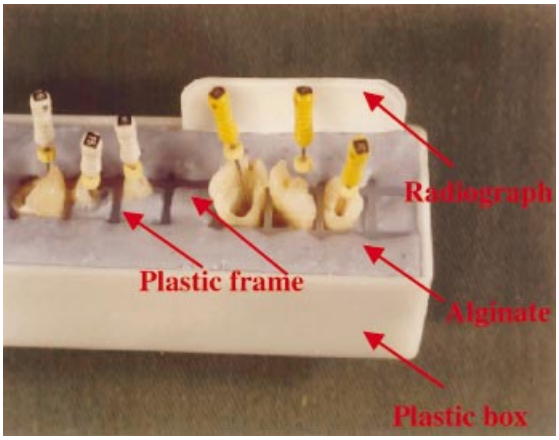


**Figure 2** Alginate model with embedded teeth.

Teeth were divided randomly into 12 groups of 10 teeth each, which were then embedded in an alginate model specially developed to test apex locators (Kaufman & Katz 1993). The model consisted of a plastic box (lid of a photograph slide box, 10 × 3 × 3 cm). When not in use, the model was wrapped with a wet paper and refrigerated to keep it in a moist environment throughout the experiment (45 days). Previous studies have shown that keeping the model in such an environment was satisfactory (Kaufman & Katz 1993). Each tooth was glued (Superglue-3, Loctite Corp, Ireland) to a plastic frame taken from a box of dental carpules (Tevacaine, Teva, Jerusalem, Israel) to form a group of 10 teeth. Alginate (Blue Print normal set, Dentsply, Weybridge, UK) was poured

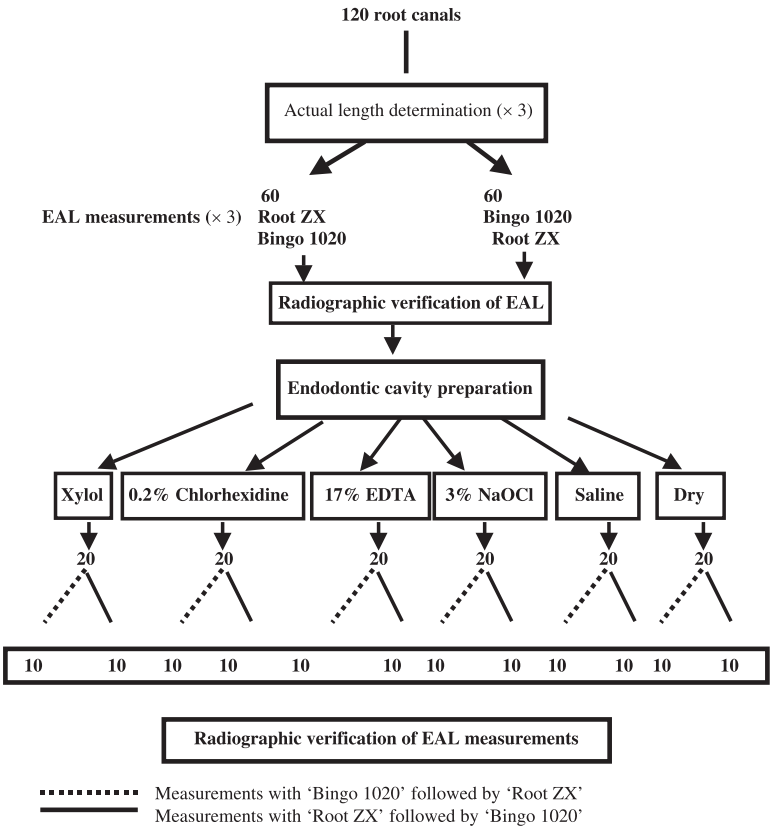


**Figure 3** Flowchart of the experiment.

into the box and the frame with the teeth was embedded into the alginate. At the inner rear side of the box, a periapical radiograph was inserted to create a space that could accommodate radiographs taken at a later stage (Fig. 2).

Figure 3 is a flowchart depicting the study design. Prior to root canal preparation, electronic tooth length (EL) measurements were carried out as follows: EL measurements of 60 teeth with the Root ZX were recorded followed by Bingo 1020, whilst on the other 60 teeth, the order was reversed. The 'apex' as indicated by both devices was chosen as the apical reference. Measurements were repeated three times and the average was calculated and computed. After the third measurement, the file was left in the root canal and a periapical radiograph taken under standardized conditions: Oralix 65 S, 220, 240 V, 5 A (momentary load) 5-/60 Hz, exposure time 0.4 s, exposure distance 12.5 Cm (Kodak Ektaspeed, Safety EO-41 Film, Rochester, NY, USA), developing time was 4 min and fixing time was 8 min (Adefo, Nuremberg, Germany). The radiographic length (RL) was determined by measuring the file on the radiograph from the coronal reference point to the tip of the file. The RL was compared to the third EL measurement only.

Each root canal was prepared using a standardized technique to a no. 40 K-file diameter (Zipperer, Munich, Germany). RC-Prep (Premier, Norristown, PA, USA) was used for lubrication and saline for irrigation. After root canal preparation, EL measurements were taken with various irrigants in the root canals:

- dry root canals;
- 3% NaOCl;
- saline;
- 0.2% chlorhexidine (Tarodent, Taro Pharmaceutical Industries Ltd, Haifa Bay, Israel);
- 17% EDTA;
- Xylol.

Each group contained 20 roots divided into two subgroups. In the first subgroup, EL measurements were taken using the Bingo 1020 followed by the Root ZX; in the second, the order was reversed. Each measurement was repeated three times and the average was calculated and computed. This average was used to compare the accuracy of each EAL and between the two devices. The third measurement was recorded radiographically, as mentioned previously.

Results were subjected to statistical analysis as follows:

**1** Effect of the order of use of the EALs on the results (ANOVA) with repeated measurements.



 

**2** Comparison between the AL and the initial electronic measurements before preparation of the root canal (paired *t*-test).
**3** Comparison between the AL and the EL obtained by each EAL after completion of canal preparation in the presence of the various irrigants (post hoc test Tukey's methods).
**4** Comparison between the AL, the RL and the EL before and after preparation of the root canal (ANOVA with repeated measurements).

## Results

### Order of measurements

Statistical analysis showed that the order of the measurements had no effect on the results ($P = 0.279$). The mean difference between the AL and the length measured by the Root ZX was −0.32 mm (SE 0.04) and Bingo 1020 − 0.24 mm (SE 0.04). A positive correlation of 0.758 ($P = 0.000$) existed between the measurements of the two EALs (Fig. 4). The distribution of the measurements between the two EALs is presented in Figure 5.

### Root canal content

The electronic measurements of both devices were shorter than the AL (average range between −0.01 and −0.57 mm). No significant statistical difference was found between the two devices ($P = 0.344$) (Table 1). Statistical differences were found amongst the different canal contents ($P = 0.000$). In the presence of EDTA and saline,

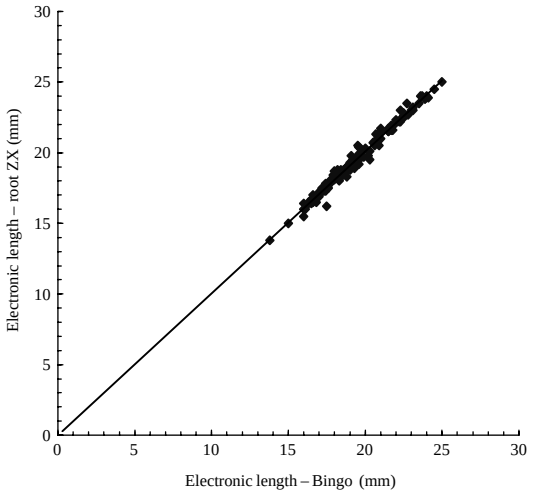


**Figure 4** Correlation between measurements of the apex locators.

**Table 1** Mean differences between the AL and the EL, measured by each apex locator in the presence of different media in the root canals (in mm)

| Medium | Root ZX (SE) | Bingo 1020 (SE) |
|---|---|---|
| Dry | −0.57 (0.10) | −0.56 (0.08) |
| NaOCl | −0.34 (0.10) | −0.33 (0.08) |
| EDTA | −0.05 (0.10) | −0.01 (0.14) |
| Saline | −0.13 (0.15) | −0.04 (0.14) |
| Chlorhexidine | −0.34 (0.11) | −0.44 (0.10) |
| Xylol | −0.52 (0.09) | −0.48 (0.11) |

$n = 20$ for each medium.

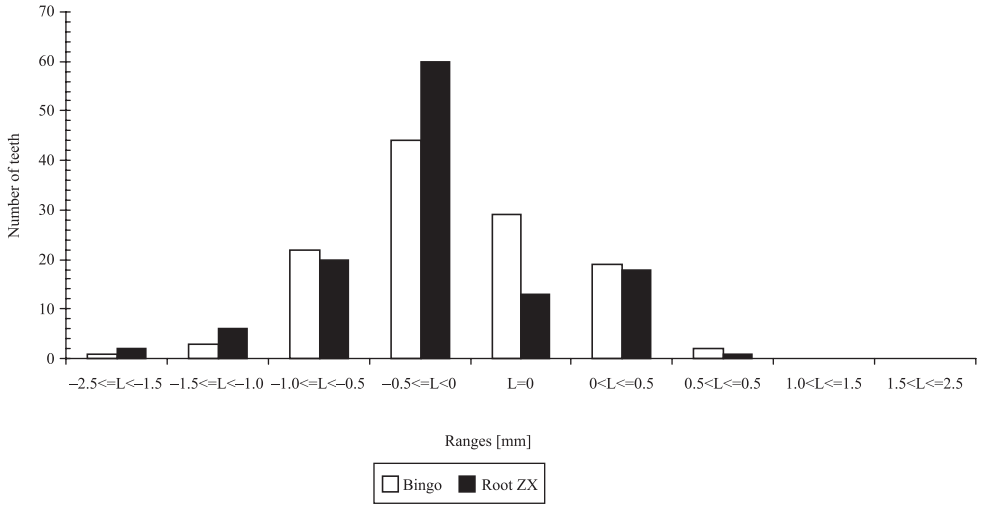


**Figure 5** Distribution of measurements of the tested EAL. (L = EL) ($n = 20$).

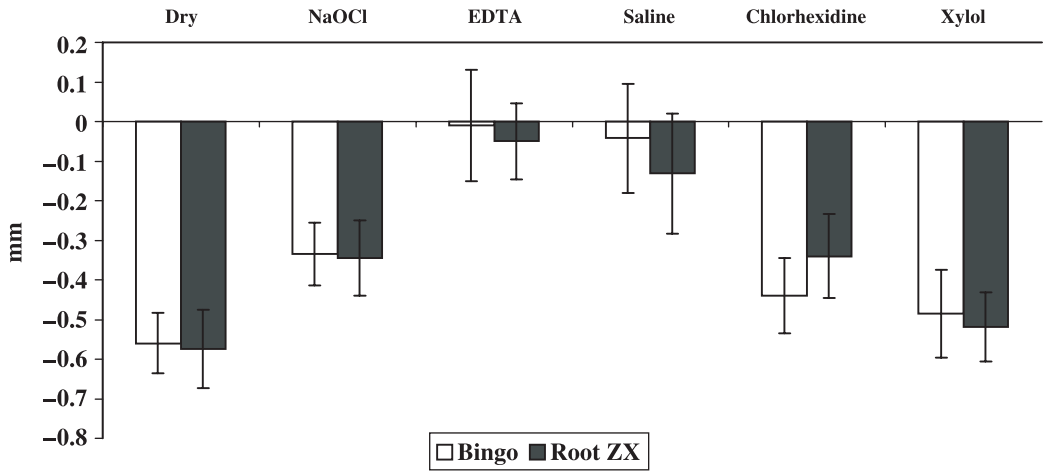


**Figure 6** Mean differences between the AL and EL in the presence of different irrigants in the root canals ($n$ = 20 for each irrigant).

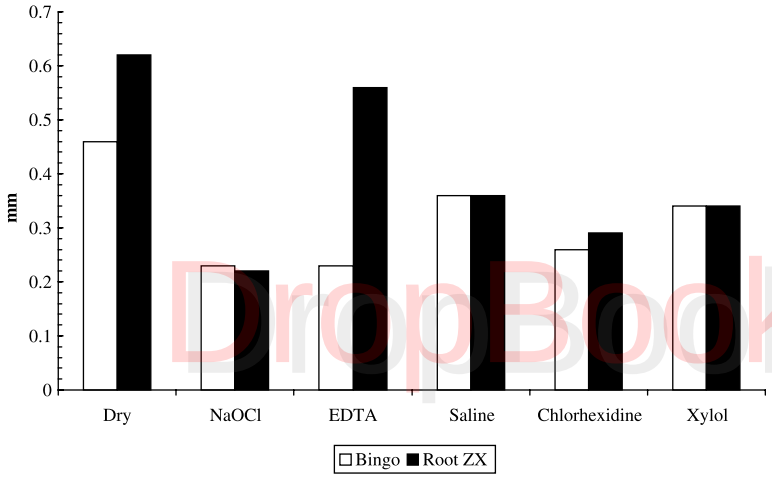




**Figure 7** Diagrammatic presentation of the mean differences between EL and the RL compared to the AL ($n$ = 20 for each irrigant).

measurements were closer to the AL, whilst those carried out in dry canals or in the presence of Xylol were shorter (range of ≥0.5 mm) (Fig. 6).

### EL compared to RL

Another objective was to compare the radiographic length (RL) to that obtained electronically and to the AL (Fig. 7). A statistical difference was found between the two devices. Measurements obtained by the Bingo 1020 were closer to the AL than those obtained by the Root ZX ($P$ = 0.035). The RL measurements with the file in the position determined by the EALs were longer than the AL values. The mean differences between the EL of the Bingo 1020 and the Root ZX were −0.18 (SE 0.06) and −0.38 (SE 0.06), respectively, and the RL 0.13 (SE 0.07) and −0.03 (SE 0.07), respectively, as compared to the AL. RL measurements with the Bingo 1020 gave longer results than the AL (Fig. 7). However, radiographic examination revealed that the files were confined within the root canals.

The same phenomenon was observed when the experiment was repeated on completion of the canal preparation with the different root canal contents. The radiographic measurements were longer than those obtained by the EALs ($P$ = 0.000) (Table 2). Radiographic verification of the EL obtained by the Bingo 1020 was usually longer than the AL but still confined within the root canal (Table 2).

## Discussion

Root length determination is a crucial factor for successful root canal treatment (McDonald 1992, Cohen &

**Table 2** Mean differences between EL and RL compared to AL in different contents of the root canals (in mm)

| | Root ZX | | Bingo 1020 | |
|---|---|---|---|---|
| Medium | EL (SE) | RL (SE) | EL (SE) | RL (SE) |
| Dry | −0.64 (0.16) | −0.02 (0.15) | −0.30 (0.14) | 0.16 (0.11) |
| NaOCl | −0.27 (0.15) | −0.05 (0.16) | −0.11 (0.17) | 0.12 (0.19) |
| EDTA | 0.09 (0.12) | 0.65 (0.07) | 0.09 (0.32) | 0.32 (0.32) |
| Saline | −0.37 (0.24) | −0.01 (0.24) | 0.24 (0.10) | 0.60 (0.13) |
| Chlorhexidine | −0.23 (0.14) | 0.06 (0.14) | −0.44 (0.11) | −0.18 (0.12) |
| Xylol | −0.39 (0.09) | −0.05 (0.16) | −0.19 (0.11) | 0.15 (0.18) |

$n$ = 20 for each medium.

Burns 1998). The traditional radiographic method has shortcomings (Kaufman & Katz 1993), including its inaccuracy (Stein & Corcoran 1992). Since their introduction, electronic apex locators have gained in popularity, especially since the development of the most recent generation. This generation uses two frequencies and enables tooth length measurements in the presence of electrical conductive media in the root canals (Kobayashi 1995). Accuracy of the recent generation of EAL averages around 90% (Fouad *et al.* 1993, Frank & Torabinejad 1993, Lin *et al.* 1993, Mayeda *et al.* 1993, Ulman *et al.* 1996). An EAL that further improves the accuracy rate is desirable and, if proven to be a reliable tool, could potentially replace, in many instances, the classic radiographic method for tooth length determination.

The manufacturers of the Bingo 1020 claim that their measuring method (based on root mean square) to locate the position of the file as it advances in the root canal produces more accurate measurements. This study tested that claim by comparing the Bingo 1020 to the Root ZX in an *in vitro* model. The reference point was the actual length (AL) as measured by introducing a file until it was seen in the apical foramen. Initial measurements (before root canal preparation) revealed that measurements obtained using the Bingo 1020 were constantly closer to the actual length than those of the Root ZX (average 0.08 mm). Although this difference was statistically significant, it has no clinical relevance. Similar results were obtained after completion of the root canal preparation and measuring the root canals in the presence of different irrigants, with the exception of chlorhexidine.

Chlorhexidine digluconate is antiseptic and has an affinity to hydroxyapatite. It has been suggested as an irrigant and as an intracanal medication (Kuruvilla & Kamath 1998, Lindskog *et al.* 1998, Segura *et al.* 1999). To date, no study has been conducted to test the effect of this solution on electronic measurements. The results of the present study indicate that the electronic measurement in the presence of chlorhexidine can be performed safely because the results are similar to those obtained in the presence of NaOCl.

Xylol is often used in retreatment cases. Its effect on electronic measurements has not been investigated. The results of this study indicate that measurements in the presence of Xylol give shorter results (average 0.5 mm). Thus, relying on these measurements alone could lead to an incomplete debridement of the root canal system.

With both EALs, EDTA and saline gave the closest results to the actual length. Thus, these irrigants can be considered as reliable solutions for electronic measurements.

Comparisons were made between electronic and radiographic measurements performed before and after root canal preparations. The *in vitro* model provided an opportunity to take the radiographs with ideal geometrical relationships. However, a statistically significant difference was found when comparing the electronic measurement to the radiographic one. Compared to the actual length, the radiographic measurements were longer (average 0.35 mm), whilst the electronic measurements were shorter (average 0.4 mm). No statistical difference was found between the two EALs regarding this finding. These results are in accordance with Stein & Corcoran (1992), who found a difference of 0.7 mm between the real file positions to that calculated on radiographs. Today, the common practice is to verify electronic measurements by radiographs and to refer to the radiographs as the most reliable source for root length determination (Cohen & Burns 1998). The result of this *in vitro* study needs to be verified in an *in vivo* study.

## Conclusions

**1** Bingo 1020 is a user friendly apex locator and is distinguished by its advanced user interface and the large and clear graphic screen, which shows a realistic display of the file advancement throughout the root canal length.

**2** Bingo 1020 measured the tooth length within a clinically acceptable range.

**3** The content of the root canal influenced the results of the measurements with both EALs, but the differences were not clinically significant.

**4** Measurements obtained using the Bingo 1020 were closer to the actual length than those obtained by the Root ZX but this had no clinical significance.

**5** Verification of tooth length through electronic measurements indicated they were closer to the actual length than those obtained radiographically. Radiographic measurements are usually longer than the actual length.

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